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An Analysis of the Geographical Distribution of *Plasmodium ovale*

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For a long time Plasmodium ovale *was considered a very rare causal agent of malaria, but recently it has been shown to be a fairly common parasite in Africa. The authors analyse all the findings of* P. ovale *outside tropical Africa and describe its distribution. This species is distributed in 2 areas, the first confined to tropical Africa and the second to islands in the Western Pacific. The authors make a medico-geographical analysis of the distribution of* P. ovale, *and attempt to explain particular features of it.*

Plasmodium ovale Stephens 1922 was for a long time considered to be a very rare causal agent of malaria, but has recently been attracting greater attention.

Ovale malaria has a number of distinguishing features, particularly the difficulty of detecting it, the length of its course, and its special area of distribution. As yet it is not clear to what extent this form of malaria will yield to control measures, but it is probable that the same sort of difficulties may arise in clearing foci of ovale malaria as are already occurring with quartan malaria.

The number of articles dealing with the distribution of *P. ovale* and particularly the extensive review by Lacan [2] is evidence of the increasing interest in this species. In Lacan's review, the collection of a vast amount of factual material makes it possible for the first time to gain a clearer idea of the limits of distribution of this particular parasite in Africa. References given by Lacan [2] concerning the findings of *P. ovale* outside Africa suggest that this parasite has a world-wide distribution. The aim of our study is to assess the reliability of this conclusion.

P. ovale has recently been diagnosed more frequently in Africa, but hardly at all in other continents, despite the large increase in the number of blood slides examined in connexion with malaria eradication campaigns. Most of the findings of *P. ovale* outside Africa relate to the end of the 1930s and to the 1940s when this new species of parasite became, so to speak, fashionable. During these years, there were single findings which were not followed up from an epidemiological point of view and which were often described in such a way as to throw doubt on the correctness of the diagnosis.

It is well known that some stages of *P. ovale* are similar to both *P. vivax* and *P. malariae*. The basic criteria for the differential diagnosis of *P. ovale* are the early appearance of James' stippling in infected erythrocytes, the compactness of the trophozoites and the specific shape of some of the infected red blood cells. These differences can be recognized only in thin films, properly stained. In the thick film the recognition of *P. ovale* is difficult and at times even impossible (James, Nicol & Shute, 1933; Lacan [3]). In mass surveys, however, as a rule only thick films are used and, moreover, few microscopists are well acquainted with the morphology of *P. ovale*.

Until recently, during mass surveys, most cases of ovale malaria have been incorrectly diagnosed, and the impression has been formed that the causal agent of this type of malaria is extremely rare. Thus Young & Johnson (1949) in a survey in Liberia, covering 10 128 persons, found *P. vivax* in 2% of cases. Bray (1957b), in a survey of 635 Liberians

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[2] Lacan, A. (1965) Plasmodium ovale *Stephens 1922, sa distribution en Afrique* (Unpublished document WHO/Mal/525.65). A limited number of copies of this document is available to persons officially or professionally interested on request to Distribution and Sales, World Health Organization, 1211 Geneva, Switzerland.

[3] Lacan, A. (1962) Plasmodium ovale *in French-speaking countries in Africa* (Unpublished document WHO/Mal/363). A limited number of copies of this document is available to persons officially or professionally interested on request to Distribution and Sales, World Health Organisation, 1211 Geneva, Switzerland.

8 years later, found *P. vivax* only once, whereas 4.4% of those examined were infected with *P. ovale*. It may be supposed that the parasites defined by Young & Johnson as *P. vivax* were in fact *P. ovale*.

Diagnosis is also made more difficult by the fact that this species is found alone in only 38% of cases, being more commonly found in association with *P. falciparum* (50%), *P. malariae* (4%), or with both species (8%) (Lacan, 1965). In ovale malaria the level of parasitaemia is as a rule low, so that in the presence of a mixed infection, it is easy to miss single parasites of *P. ovale* against a background of large numbers of ring forms of *P. falciparum*. In addition, when there is a mixed infection, *P. ovale* like *P. vivax*, is suppressed by *P. falciparum*.

ANALYSIS OF FINDINGS OF *P. OVALE* OUTSIDE AFRICA

Taking into account the special features of the morphology and ecology of the parasite, we have subjected the findings of *P. ovale* outside tropical Africa to a critical analysis; some of these findings are quoted by Lacan.[1] The results of our analysis are shown in the accompanying table. Other authors have also had doubts about the authenticity of finding of *P. ovale* outside Africa. Sinton, Hutton & Shute (1939) wrote that at least in some of the cases in which the parasite had been found outside Africa, unusual forms of *P. vivax* and *P. malariae* had been mistaken for *P. ovale*. Nikolaev (1951) demonstrated the doubtful authenticity of all 4 findings of *P. ovale* in the USSR (cases 7, 12, 13 and 19 in the accompanying table), although these are still quoted as authentic by many workers (Russell et al., 1963; Lacan [1]). Later, Young, Eyles & Burgess (1948) and Young & Eyles (1949) warned against the incorrect diagnosis of *P. ovale* among soldiers returning from the Pacific theatre of operations, stating that when *P. vivax* from New Guinea was passaged, *ovale*-like forms appeared from time to time in blood.

The erroneous identification of local cases of *P. ovale* may be due not only to the shortcomings of a laboratory diagnosis. In the absence of an epidemiological follow-up, some cases regarded as local could, in fact, have been cases of imported or induced malaria. Moreover, the possibility of the infection of man by simian malaria cannot be considered out of the question.

Already 5 species of simian plasmodium are known which can be transmitted to man (*P. cynomolgi*, *P. knowlesi*, *P. simium*, *P. inui* and *P. brasilianum*) and in the case of the first 3 species, infection has occurred under natural conditions.[2] Some simian parasites are very similar to human plasmodia. In particular, *P. fieldi*, *P. simiovale*, and according to some classifications *P. simium*, belong to the same group as *P. ovale*. It is therefore quite possible that in some of the reported cases one of the simian parasites has been mistaken for *P. ovale*.

In view of the possibility that *ovale*-like forms may occur in human malaria plasmodia, we consider that a local case of ovale malaria recorded outside tropical Africa can be considered as authentic only if it fulfils the following conditions:

(1) that an experimental study of the detected strain has been made by passage in human beings, proving that it is indeed *P. ovale*;

(2) that, in the patient concerned, a series of blood preparations taken at various periods of the illness have been studied, without any change being found in the morphological characteristics of the parasite; and

(3) that, in the area concerned, several cases of ovale malaria have been detected, and that the patients have been studied with sufficient care (by examination of a series of blood preparations, and by a clinical follow-up).

If these criteria are adopted, the cases given in the accompanying table may be divided into the following groups:

(A) Cases known to be unreliable:

(*a*) cases in which the identity of the parasite with *P. ovale* was not confirmed by experimental study (cases 3 and 7);

(*b*) cases with mixed *P. vivax* and *P. ovale* infection in which there was no proof that it was not *ovale*-like forms of *P. vivax* that were present (cases 8, 17 and 20).

(B) Very doubtful cases not properly described (cases 2, 4, 6 and 19).

[1] Lacan, A. (1965) Plasmodium ovale *Stephens 1922, sa distribution en Afrique* (Unpublished document WHO/Mal/525.65). A limited number of copies of this document is available to persons officially or professionally interested on request to Distribution and Sales, World Health Organization, 1211 Geneva, Switzerland.

[2] Bruce-Chwatt, J. L. (1966) *Malaria as a zoonosis* (Unpublished document WHO/Zoon/66.90, WHO/Mal/66.578). A limited number of copies of this document is available to persons officially or professionally interested on request to Distribution and Sales, World Health Organization, 1211 Geneva, Switzerland.

ANALYSIS OF FINDINGS OF *P. OVALE* OUTSIDE TROPICAL AFRICA

Author and place of description	Assumed place of infection	Diagnosis by the author	Method of establishing the diagnosis	Analysis of the cases
1. Craig (1900), also Craig & Faust (1951)—USA	Philippines	First, *P. vivax* var., the *P. vivax* var. *minutum*, finally *P. ovale*	Identified as *P. ovale* after re-examination of the preparations in 1933	Although the diagnosis was established retrospectively, without epidemiological investigation, it is possible that this really was a case of *P. ovale* in view of later findings (case 21)
2. Heydon (1923)—Rabaul, New Britain	Duke of York Island, Bismarck Archipelago	Forms reminiscent of *P. vivax* var. *minutum* (Emin); later *P. ovale*	Retrospectively by study of the preparation obtained during a mass survey	According to McMillan & Kelly (1966), Heydon, having learnt of Stephens' discovery, identified the parasite he found as *P. ovale*. No description or illustrations of the parasite were ever published
3. Plehn (1924)—Germany	Palestine	An unusual strain of malaria parasite distinguished by its diurnal periodicity and lack of gametocyte production	Passages in persons suffering from general paralysis of the insane	Identified with *P. ovale* by many authors (e.g. Brumpt, 1949; Lacan [a]). According to Brumpt (1949) this strain after 20 passages suddenly changed its properties and turned into ordinary *P. vivax*
4. Mühlens 1934—Germany	West coast of South America	*P. ovale*	Retrospectively, on the basis of the preparation in the collection	No description or illustration of the parasite is given. No epidemiological survey was carried out and the place of infection remains obscure
5. Mageed (1936)—Egypt	Near Zagazig, Lower Egypt	*P. ovale*	Retrospectively on the basis of a slide taken during a mass survey	Description very brief. Some characters not typical of *P. ovale*. No epidemiological survey
6. Mühlens 1938	Iran	*P. ovale*	?	Described as a " case of ovale malaria from Persia ". No description or illustration of the parasite is given and there is no indication as a whether there was an epidemiological investigation
7. Eskin (1938)—Tashkent, USSR	Neighbourhood of Ufa in Bashkiria, USSR	To begin with *P. vivax* + *P. ovale*; later *P. ovale*	Passages in blood and through mosquitos	The strain differed from *P. ovale* morphologically and biologically (see Nikolaev, 1951). In an editor's note to the article by Lisova et al. (1946), summing up the study of the strain, doubt is expressed as to it being *P. ovale*
8. Shieber (1939)—Palestine	Neighbourhood of Haifa, Palestine	*P. vivax* + *P. ovale*	Blood-slide examination	In view of the possibility of the occurrence of *ovale*-like forms in *P. vivax*, it seems improbable that such a difficult task as the establishment of a correct diagnosis of a mixed infection with *P. vivax* and *P. ovale* would have been correctly carried out in the initial period of study of *P. ovale*. In subsequent years no cases of ovale malaria of local origin were described from Palestine
9. Papafigou (1939)—Greece	First case from E. Macedonia, second from S. Epirus	*P. ovale*	Retrospective diagnosis from blood-slide examination	Some features in the parasites described are not typical of *P. ovale*. No epidemiological survey
10. Mendez (1939) Venezuela	Venezuela	*P. ovale*	?	Original paper not seen

ANALYSIS OF FINDINGS OF *P. OVALE* OUTSIDE TROPICAL AFRICA (*continued*)

Author and place of description	Assumed place of infection	Diagnosis by the author	Method of establishing the diagnosis	Analysis of the cases
11. Raman (1940) —India	Vizagapatam, Andhra-Pradesh, India	*P. ovale*	Blood-slide examination	Despite the author's assertions, the photomicrographs printed do not confirm his diagnosis. Some of the parasites are *P. falciparum*
12. Matevosjan (1940)— Armenia, USSR	Armenia, USSR	*P. ovale*	Retrospectively, on the basis of one preparation	Judging from the description and the illustrations, the parasite found differs somewhat from *P. ovale*. The case cannot be considered as reliable since no epidemiological investigation was carried out
13. Gvelisiani (1940)— Georgia, USSR	Georgia, USSR	*P. ovale*	On the basis of several preparations made at one and the same time	A sufficiently complete description of the parasite is not available. There are a number of features uncharacteristic of *P. ovale*. The case was not investigated
14. Garcia (1941) —Manila, Philippines	Manila, Philippines	*P. ovale*	Blood-slide examination. Clinical observations	Judging from the description, the author was probably dealing with *P. ovale* of local origin. The discovery of the Donaldson strain (see case No. 21) confirms Garcia's finding
15. Yao & Wu (1941)— Kungming, Yunnan, China	Southern China	*P. falciparum* + forms reminiscent of *P. ovale*	Retrospectively on the basis of several smears	A most careful description of a parasite which resembles *P. ovale*, although it possesses some features not characteristic of that parasite. No additional blood examination or epidemiological follow-up. It is not impossible that this may be an infection with simian malaria in a human patient
16. Ganov (1941) —Bulgaria	South-eastern frontier of Bulgaria	*P. ovale*	?	Original paper not seen
17. de Zulueta (1942)— Colombia	Colombia	*P. vivax* + *P. ovale*	On the basis of slides taken during 4 hours on the same day	The author's statement that intermediate forms between *P. vivax* and *P. ovale* were present in the blood preparations and the absence of any evidence other than morphological, makes it doubtful whether the patient's blood contained *P. ovale*
18. Jackson (1944)— New Guinea— 2 cases	Neighbourhood of Port Moresby, Papua	*P. ovale*	(*a*) First case—series of preparations taken on various days of the illness in the absence of specific therapy (*b*) Second case—blood-slide examination on a single occasion and clinical observation	Both cases are undoubtedly of local origin. The first of them was studied very carefully. It is quite probable that the author was dealing with *P. ovale*
19. Fridman (1946)— Tvilisi, Georgia, USSR	?	*P. ovale*	Blood-slide examination	The description is extremely short and it is impossible to know what species of parasite was involved

ANALYSIS OF FINDINGS OF *P. OVALE* OUTSIDE TROPICAL AFRICA (*concluded*)

Author and place of description	Assumed place of infection	Diagnosis by the author	Method of establishing the diagnosis	Analysis of the cases
20. Gurevitch & Laufer (1952) —Israel	Neighbourhood of Mosul, Iraq	*P. vivax* + *P. ovale*	Blood-slide examination	There is no description or illustration of the parasite. The case was not investigated in detail and it is possible that this was a case of induced malaria. The possibility of establishing a correct diagnosis of mixed infection with *P. vivax* and *P. ovale* after such a short investigation is also doubtful
21. Jeffery, Young & Willcox (1954)—USA	Luzon, Philippines	*P. ovale*	Passages in blood and through mosquitos	Careful experimental study of the strain isolated (the Donaldson strain) demonstrated that it belonged to *P. ovale*
22. Quoted by Mukherjea, Chatterjee & Paul (1966). Original paper published in 1960—India	Calcutta, India	*P. ovale*	?	Original paper not seen
23. Jevtić & Bokić (1965) —Yugoslavia	East Pakistan	*P. ovale*	Two slide taken 2 and 17 hours respectively after an attack	It is most probable that infection did not occur in Pakistan where the patient had been 15 months before the illness, but in Togoland which he had left 34 months earlier. Long-term relapses of this kind have been described by other authors in regard to ovale-malaria: in these other cases 20 and 44 months (Trager & Most, 1963) and 52 months (Dixit, 1958) had elapsed since the patients' return from malarious areas
24. Mukherjea, Chatterjee & Paul (1966)— Calcutta, India	East Pakistan or West Bengal (India)	*P. ovale*	Retrospectively, on the basis of one preparation	The description given is very brief. Some features of the parasite are not typical of *P. ovale*. No epidemiological survey
25. McMillan & Kelly (1967)— New Guinea	Eastern part of New Guinea	*P. ovale*	Blood-slide examination and clinical observation	Case 25 was studied in sufficient detail. In cases 26 and 27 there was no epidemiological survey. No additional parasitological examinations were made. In view of the fact that case 25 is territorially linked with case 18, the authors may have encountered *P. ovale*
26. McMillan & Kelly (1967)— New Guinea	Eastern part of New Guinea	*P. ovale*	Thin film	
27. McMillan & Kelly (1967)— New Guinea	Solomon Islands	*P. ovale*	On the basis of a collection preparation made by Price in 1942	
28. Alves, Schinazi & Aniceto (1968)— Philippines	Neighbourhood of Puerto Princesa, Palawan, Philippines	*P. ovale*	On the basis of preparations made during mass survey of prison population	Two cases, apparently linked epidemiologically. The correctness of the identification has been confirmed by Professor Garnham

[a] Lacan, A. (1965) Plasmodium Ovale *Stephens 1922, sa distribution en Afrique* (Unpublished document WHO/Mal/525.65). A limited number of copies of this document is available to persons officially or professionally interested on request to Distribution and Sales, World Health Organization, 1211 Geneva, Switzerland.

(C) Doubtful cases:

(*a*) cases in which there was retrospective determination on the basis of one preparation, or of several taken at the same time, without epidemiological investigation or a series of parasitological examinations. In some cases the parasite possessed characteristics not typical of *P. ovale* (cases 5, 9, 11, 12, 13, 15, 18b, 24, 25, 26, and 27);

(*b*) cases in which the precise place where infection occurred was not known (case 23).

(D) Probable cases:

(*a*) cases in which the description of the parasite fits *P. ovale* and in which epidemiological investigations and a series of parasitological examinations were carried out (case 18a);

(*b*) cases in which the description of the parasite fits *P. ovale* and which occurred in areas where the existence of *P. ovale* has been proved (cases 1, 14, and 28).

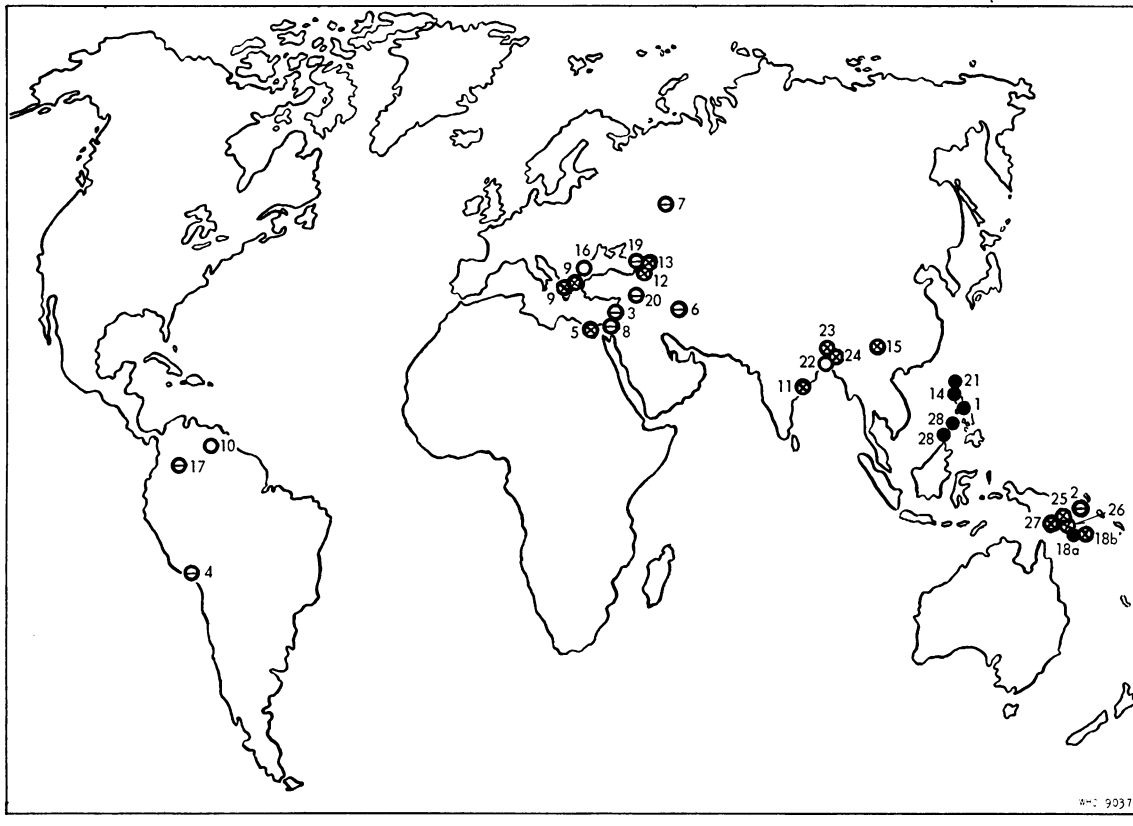
(E) Reliable cases in which the parasite has been proved experimentally to be *P. ovale* (case 21).

(F) Cases which cannot be classified because of the inadequacy of the information available (cases 10, 16 and 22).

Thus, it may be said with confidence that in addition to tropical Africa, *P. ovale* is encountered in the Philippines (Fig. 1) and possibly in New Guinea also. It may also be found in some areas of South-East Asia, although this is less likely. There is no clear evidence that it is endemic in other areas in

FIG. 1

SITES AND CLASSIFICATION OF FINDINGS OF *PLASMODIUM OVALE* OUTSIDE TROPICAL AFRICA



⊖ Clearly unreliable and very doubtful (groups A and B)

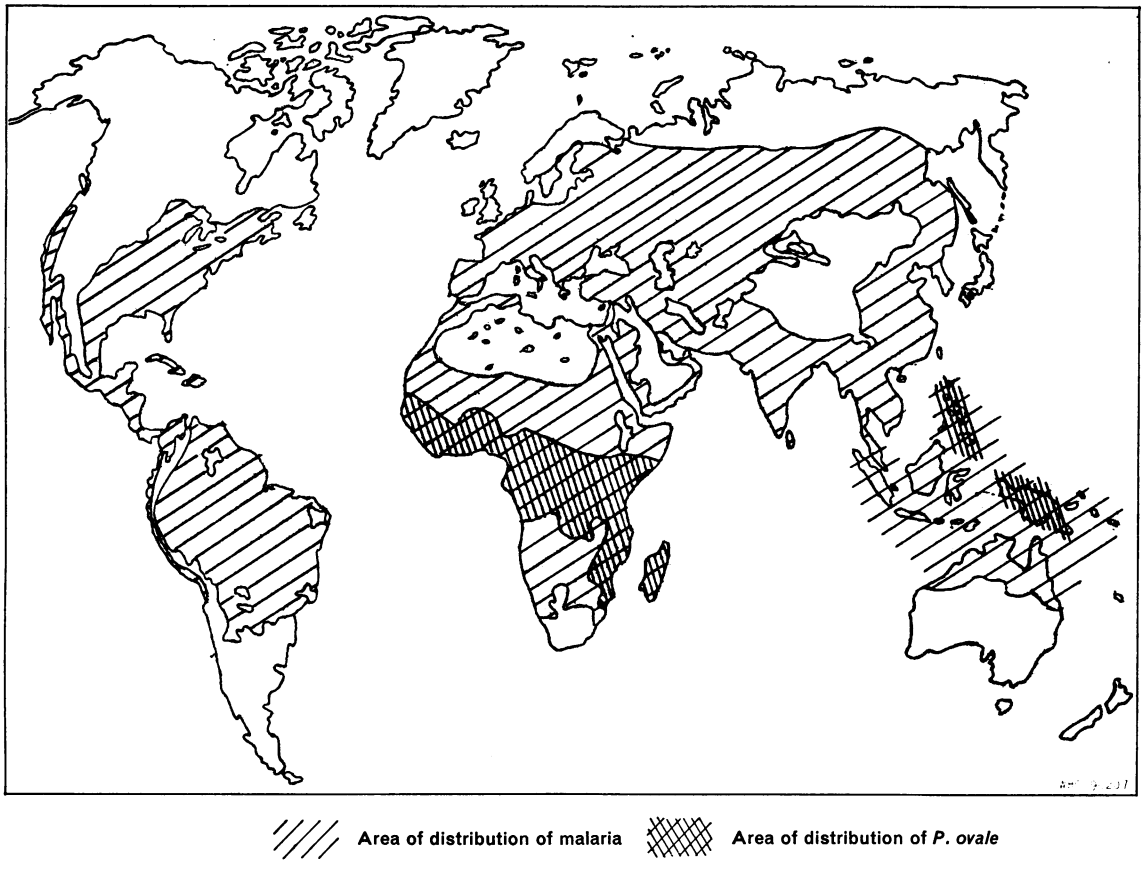
⊗ Doubtful (group C)

● Reliable and probably correct (groups D and E)

○ Cases for which there is no information (group F)

[a] The numbers by the sites on the map correspond with the numbers in the table.

FIG. 2
AREA OF DISTRIBUTION OF *PLASMODIUM OVALE* AND THE ORIGINAL AREA OF DISTRIBUTION OF MALARIA



the world. On the basis of what has been stated we suggest that the distribution of *P. ovale* is confined to tropical Africa and to islands in the Western Pacific (Fig. 2).

MEDICO-GEOGRAPHICAL ANALYSIS OF THE DISTRIBUTION OF *P. OVALE*

As will be seen from Fig. 1 the area of distribution of *P. ovale* is peculiar in extent, shape and structure. In size it is much smaller than the area of distribution of any of the other species of human malaria parasites. In shape it is discontinuous, with a break in the Indian subcontinent, and there is no doubt that tropical Africa should be considered as its " centre of abundance ".[1]

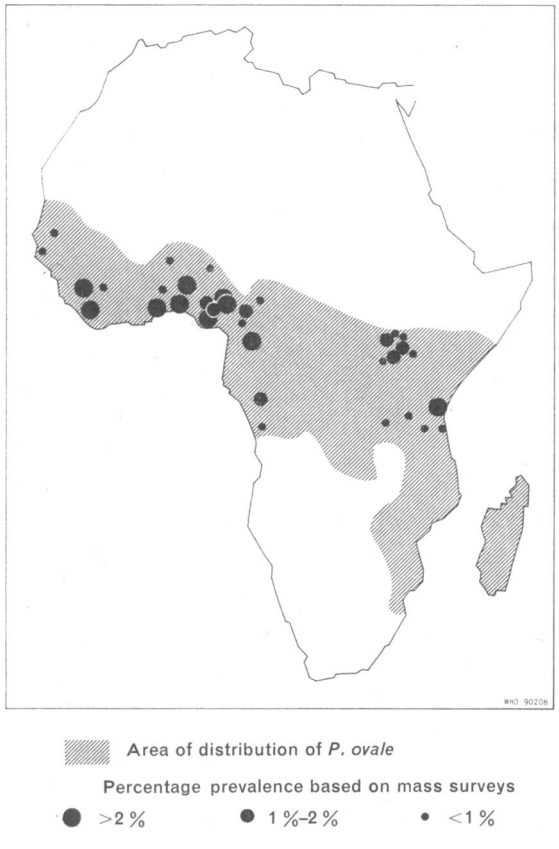
Although nowhere in Africa does *P. ovale* occupy a dominant position among the species of malaria parasites, in some foci (e.g., in Liberia) the prevalence does reach 10%. In the islands of the Western Pacific only sporadic cases of ovale malaria occur.

We have attempted to prepare a map showing the distribution of *P. ovale* in Africa, by using data from original sources and from Lacan's review [2] (Fig. 3). In compiling the map we found that data for the various areas were rarely comparable. In the first place, the earlier sources always gave figures that were too low; secondly, prevalence is given for

[1] " Centre of abundance " (*centr obilija*): the part of the area of distribution where the species in question is most commonly encountered (Voronov, 1963).

[2] Lacan, A. (1965) Plasmodium ovale *Stephens 1922, sa distribution en Afrique* (Unpublished document WHO/Mal/525.65). A limited number of copies of this document is available to persons officially or professionally interested on request to Distribution and Sales, World Health Organization, 1211 Geneva, Switzerland.

FIG. 3
AREA OF DISTRIBUTION OF *PLASMODIUM OVALE* IN AFRICA



different population groups in different papers, and thirdly, the standards of diagnosis differed in the different areas. Otherwise it would be impossible to explain the fact that in the north-eastern areas of Liberia, on the borders with Guinea, the prevalence of *P. ovale* among the population is very high, rising to 4.4% (Bray, 1957b), whereas in Guinea itself not a single finding of the parasite has been reported. However, *P. ovale* is in fact quite often encountered in Guinea, as is shown by the fact that out of 55 imported cases of ovale malaria recorded in the USSR in the 1963-67 period, 21 originated in Guinea (figures supplied by the Malaria Prophylaxis Department of the Marcinovskij Institute of Medical Parasitology and Tropical Medicine). Cases of ovale malaria have also occurred in the USSR which had been imported from Portuguese Guinea and Mali, also countries in which, according to Lacan,[1] *P. ovale* has never been recorded. The study of imported cases has enabled us to determine more precisely the limits of the distribution of *P. ovale*. The incidence of *P. qvale* remains unknown in some extensive areas, with different natural conditions such as the Democratic Republic of the Congo, Mozambique, etc.

Despite the numerous gaps, however, the main features of the distribution of *P. ovale* are clear. In Africa the " centre of abundance " is close to the northern coast of the Gulf of Guinea while the area of distribution covers the rest of tropical Africa. The portion of the area of distribution in the Pacific may be considered as an area where the infection was introduced. It is of interest to analyse possible links between the component parts of the area of distribution of *P. ovale* and the factors which may determine them.

Relation with climate

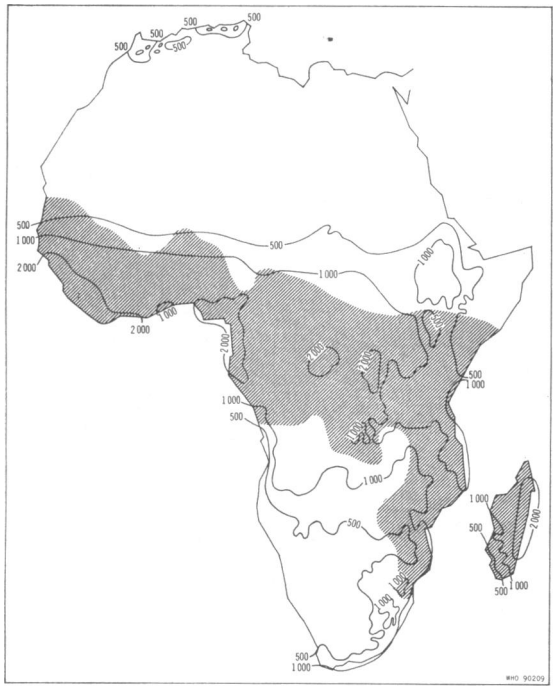
Regions with comparatively high prevalence of *P. ovale* (>2% of the population) are confined to the area of equatorial forest and savanna woodland. The prevalence of *P. ovale* in West Africa decreases regularly from south to north of the region in accordance with the decrease in the rainfall (cf. Fig. 3 and Fig. 4).

In woodland savanna areas it is often as widespread as in the neighbouring forests (Lacan & Peel, 1958; Choumara [2]) and this indicates that the distribution of *P. ovale* is not directly influenced by the type of vegetation, but by climatic conditions. However, although the centre of abundance lies in the tropical forest zone, with its hot humid climate, the parasite is also found far beyond its limits, along the lower course of the River Senegal almost to the borders of the desert. On the other hand, in areas of the world with roughly identical climatic conditions, prevalence ranges from comparatively high in Africa to sporadic in the Western Pacific and to zero in the tropical areas of South and Central America.

[1] Lacan, A. (1965) Plasmodium ovale *Stephens 1922, sa distribution en Afrique* (Unpublished document WHO/Mal/525.65). A limited number of copies of this document is available to persons officially or professionally interested on request to Distribution and Sales, World Health Organization, 1211 Geneva, Switzerland.

[2] Choumara, R. (1963) *Note on* Plasmodium ovale *in South Cameroon* (Unpublished document WHO/Mal/387). A limited number of copies of this document is available to persons officially or professionally interested on request to Distribution and Sales, World Health Organization, 1211 Geneva, Switzerland.

FIG. 4
AREA OF DISTRIBUTION OF *PLASMODIUM OVALE* IN AFRICA AND DISTRIBUTION OF RAINFALL



Relation with the vector fauna

It is possible that these differences may be explained by the different species-composition of the mosquito–vector fauna in different parts of the world. In tropical Africa, the main vector of malaria is *Anopheles gambiae*, and to a lesser extent *A. funestus*. It may be assumed that *A. gambiae* is a more effective vector of *P. ovale* than *A. minimus flavirostris* and *A. punctulatus*, which are the main malaria vectors in the Philippines and New Guinea respectively. Differences in prevalence in Africa could be ascribed to the fact that *A. gambiae* represents a species complex, different constituents of which may behave differently in respect of *P. ovale*. The range of one of the species in the complex, *A. gambiae* sp. A, roughly corresponds to the area with the greatest prevalence of *P. ovale*.[1] In addition a secondary vector such as *A. moucheti*, which is widespread in the forest areas of Africa, may play a role in the transmission of *P. ovale*.

This suggestion contradicts the experimental findings, however, since it is well known that mosquito vectors from other zoogeographical regions are susceptible to infection with *P. ovale*. The Liberian strain and the Donaldson strain of *P. ovale* have been successfully transmitted through vectors from America—*A. albimanus* and *A. quadrimaculatus* (Jeffrey, Willcox & Young, 1955) and *A. freeborni* (Chin, Contacos & Buxbaum, 1966). The same applies to vectors from the Palaearctic region—*A. maculipennis atroparvus*, which has more than once been successfully infected with *P. ovale* from Africa (James, Nicol & Shute, 1932; Garnham et al., 1955) and *A. maculatus* (Chin, Contacos & Buxbaum, 1966). It should be noted, however, that the number of oocysts in non-African mosquitos has always been small. Possibly, although *P. ovale* is not strictly tied to one particular species of vector, not all the known species of *Anopheles* can ensure its endemic existence.

Relation with host susceptibility

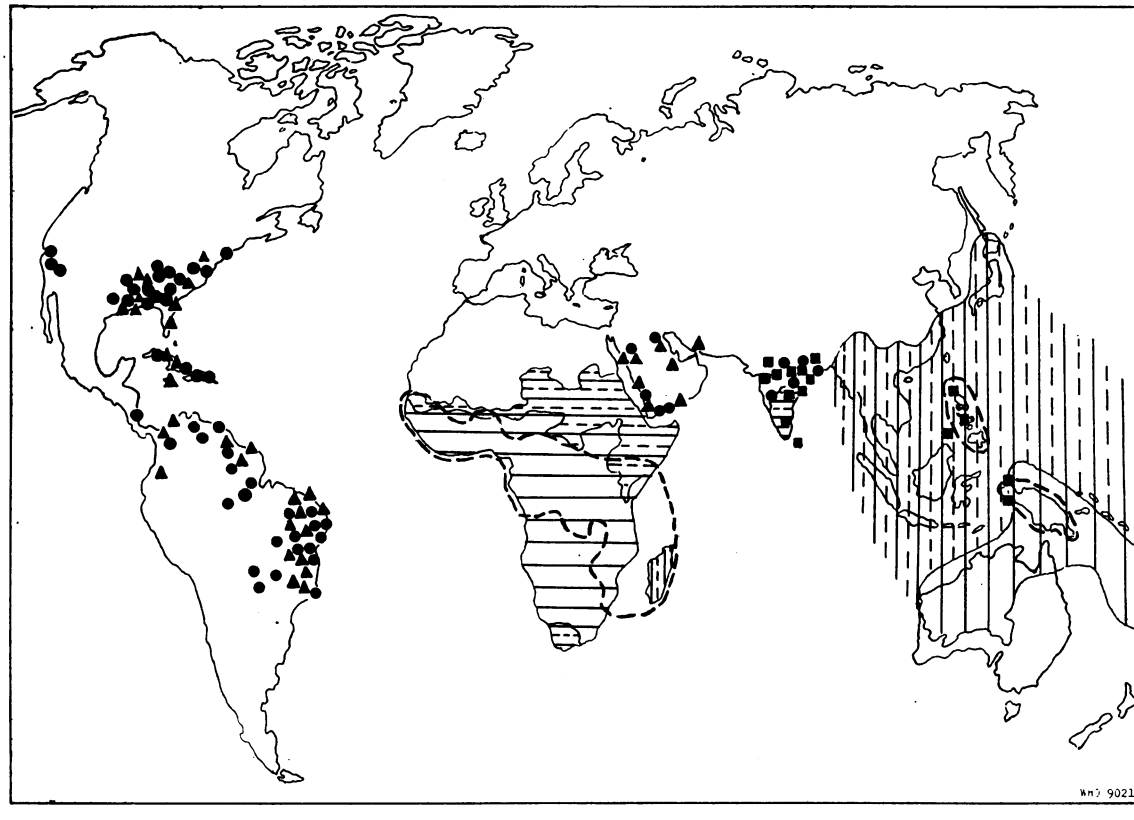
The racial composition of the population is similar in both parts of the area of distribution of *P. ovale*. On the African continent it coincides with the settlements of the Negro race and in New Guinea with the settlements of the Melanesian race (Fig. 5). According to Soviet anthropologists these 2 races, which make up the equatorial race, are of closely related origin (Debec, 1955; Nesturh, 1960; Roginskij, 1962). As regards the Philippines and Madagascar, the Mongoloid population of those islands has a strong admixture of the equatorial race, and in the Philippines, in addition, groups of pygmies, belonging directly to the equatorial race, have survived.

It is known that resistance to certain diseases may be a racial character. Thus, the bulk of the Negroid population in Africa possess a congenital resistance to *P. vivax*, as has been demonstrated experimentally (Bray, 1958). This resistance has been retained by the American Negroes. Bray (1957a) considers that

[1] Davidson, G. (1966) *Distribution records of member species of the* Anopheles gambiae *complex (identifications up to May 1966)* (Unpublished document WHO/Mal/66.570; WHO/Vector Control/66.215). A limited number of copies of this document is available to persons officially or professionally interested on request to Distribution and Sales, World Health Organization, 1211 Geneva, Switzerland.

FIG. 5

AREA OF DISTRIBUTION OF *PLASMODIUM OVALE* AND DISTRIBUTION OF PEOPLE BELONGING TO THE EQUATORIAL RACE[a]



[a] Based on *Atlas of the world's peoples*, Moscow, 1964.

P. vivax cannot exist in a purely Negro environment, although a few individuals of the Negro race do not possess resistance to it. In places where the prevalence of *P. ovale* is greatest (Nigeria, Ghana, Cameroon, Liberia and Gambia) *P. vivax* is practically absent. It is regularly found only in East Africa, where there is a Europeoid element (Arabs, Indians, Europeans and the peoples of the Ethiopian transitional race), and in Madagascar, which is mainly peopled by Mongoloids. In accordance with this, the prevalence of *P. ovale*, as far as can be judged, is lower in those territories than in West Africa. The peoples belonging to the Melanesian race, and the rest of the population of the islands of the Pacific Ocean, show no resistance to *P. vivax*, and *P. ovale* is encountered there very rarely. Although a comparison of the Liberian strain and the Donaldson strain of *P. ovale* showed that both Negroes and Caucasians are equally susceptible to both strains (Jeffrey, Willcox & Young, 1955), this does not exclude the possibility that under natural conditions very fine, almost undetectable, differences in the susceptibility of the host to the parasite, and in the formation of immunity, may come into play.

Relation with simian malaria

The features of the distribution of ovale malaria have suggested to some investigators that the disease is a zoonosis. Brumpt (1949), believing that *P. ovale* was distributed in all continents, but was encountered very rarely, wondered whether *P. ovale* was not an abrupt mutation of *P. vivax* or a malaria parasite of a vertebrate species with universal distribution. When it became clear that *P. ovale* was not so rare, but that its range was confined to certain tropical areas, Languillon (1957) suggested that *P. ovale* might be a normal parasite of apes, particularly chimpanzees. The possibility of transmission of *P. ovale* to chimpanzees, by passage through *A. gambiae*, has been experimentally proved (Bray, 1957b).

Although *P. ovale* has a wider range than the chimpanzee, and one which partly overlaps with the range of the lower catarrhine monkeys, this does not altogether exclude the possibility of the circulation of this malaria parasite between man and ape. The fact that so far no analogues of human *P. ovale*, such as are known in *P. vivax* and *P. malariae*, have been found in the anthropoid apes, does not mean that they are absent in nature, since the biological features of *P. ovale* make it difficult to detect, particularly in apes. As already suggested, it may be that in some cases *ovale*-like plasmodia of the lower primates have been mistaken for *P. ovale*.

The possibility of P. ovale *becoming entrenched outside its known area of distribution*

A number of biological features of *P. ovale*, particularly the long period of sporogony (15–16 days at 25°C, as against 10 days at the same temperature in the case of *P. vivax*), the very low and inconsistent rate of parasitaemia, the scanty production of gametocytes, and the low degree of infection of the vector create serious obstacles to its spread in areas with low temperatures and seasonal malarial transmission, with ineffective vectors or an insufficiently high population density of the vector. Some of these features are also found in *P. malariae*, but in *P. ovale* they are much more clear-cut. They may apparently be responsible for the special type of patchy distribution of both parasites inside the area of distribution of the disease. The greater duration of the course of infection in quartan and ovale malaria is apparently an evolutionary adaptation compensating for features in their biology which are unfavourable to the existence of the parasites.

In view of what has been said, when single carriers of *P. ovale* enter a region free from ovale malaria the probability of transmission from a sick to a healthy person is practically nil and this may explain to some degree why *P. ovale* has not spread out of Africa, that citadel of malaria, and why it is absent from America, where all types of malaria were imported on a huge scale with African slaves and where a number of parasitic diseases, including tropical and quartan malaria, have become entrenched.

Jeffery, Young & Willcox (1954), who studied the Donaldson strain, expressed anxiety lest the *P. ovale* imported from the islands of the Pacific Ocean should become endemic in the USA, in which case great difficulties would arise in its detection and eradication. In the light of what has been said these fears seem to be exaggerated.

CONCLUSION

In conclusion it must be pointed out that not one of the factors considered (climate, vector fauna, area of distribution of simian species and racial features of the population) is sufficient by itself to explain the special features of the range of *P. ovale*. Obviously the explanation must be sought in a complex interaction of the factors listed and possibly of others. There are grounds for supposing that the medico-geographical approach to the study of the distribution of *P. ovale* will promote the successful solution of this problem.

RÉSUMÉ

ANALYSE DE LA RÉPARTITION GÉOGRAPHIQUE DE *PLASMODIUM OVALE*

Plasmodium ovale Stephens 1922, considéré autrefois comme un parasite rare du paludisme, retient davantage l'attention depuis quelque temps. La présente étude a pour objet d'évaluer le bien-fondé des rapports signalant sa présence hors d'Afrique, de déterminer les limites de sa zone de répartition et d'analyser les particularités de celle-ci.

Les auteurs, examinant une série de rapports affirmant l'existence de cas indigènes de *P. ovale* survenus ailleurs qu'en Afrique tropicale, estiment que l'identification de *P. ovale* n'est certaine que dans quelques cas, tous observés aux Philippines et en Nouvelle-Guinée. Les autres cas signalés ne correspondent pas aux normes diagnostiques et épidémiologiques proposées dans le

présent document. Il ressort de ces études que la zone de répartition de *P. ovale* se limite à l'Afrique tropicale et à des îles du Pacifique occidental.

Les auteurs procèdent ensuite à une analyse médico-géographique de la zone de répartition de *P. ovale* en fonction du climat, des espèces de moustiques vecteurs et de la réceptivité de l'hôte. Ils envisagent également la possibilité d'une relation avec le paludisme simien.

Ils concluent qu'aucun des facteurs considérés ne suffit par lui-même à expliquer les caractères particuliers de la répartition de *P. ovale*, et que la solution du problème doit faire appel à l'interaction complexe de ces facteurs et peut-être d'autres encore. On a des raisons de penser que la méthode médico-géographique permettra de planifier les nouvelles recherches qui sont nécessaires pour expliquer les particularités de la répartition géographique de *P. ovale*.

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